APPLICATION NOTE

1001312

EVB 1001312-04

APPLICATIONS:

M2M	AUTOMOTIVE	AUTOMATIC METER
SECURITY	POINT OF SALE	TRACKING

Table of Contents

Purpose

This document provides information for incorporating Kyocera-AVX's Prestta standard embedded UWB antenna into wireless products. Specifications, design recommendations, board layout, packaging and manufacturing recommendations are included.

This document is divided into two parts: a main section and appendices. The main section addresses points and issues common to all products. The appendices provide product-specific information.

Overview

Product Selection Guide

Antenna PN	Application	Antenna PN Application Type Typical Deliverable	Typical Deliverable Size
1001312-04	• UWB Band • 6GHz~8.5GHz	• Demo Board	• Antenna Assembly on PCB board • 26 x 25 mm

Prestta Features and Benefits Summary

Features	Benefits
Ceramic Antennas with SMD capability	• Flexibility in antenna placement with direct SMT on board • Ease of manufacturing
Embedded Solutions for UWB Band	• Eliminates external antennas • More desirable form factors • Can be used in Access Points, Routers, Gateways, Wireless Displays/TVs, and other consumer electronic devices
Compact Size and High Performance	• Fit on small PCB within small devices • Comparable same level performance as in a large room
Ground Cleared Solution	• Enables flexibility in antenna placement within end device
Extensive Design Collateral and Apps Support	• Speeds development time
Standard "Off the Shelf" Product	• Standard "Off the Shelf" Product • Speeds development time and reduces costs by reducing NRE and custom development time

Design Guidelines

Introduction

The Prestta standard UWB embedded antenna can be designed into many wireless product types. The following sections explain Kyocera-AVX recommended layouts to help the designer integrate the antennas into a product with optimum performance.

Electrical Specifications

Typical Characteristics Measurements taken on a 26 x 25 mm PCB

Frequency (GHz)	6.0-8.5
Peak Gain	4.8 dBi
Average Efficiency	84%
VSWR Match	2.0:1 max
Feed Point Impedance	50 ohms unbalanced
Polarization	Linear
Power Handling	2 Watt CW

Mechanical Specifications

Ordering Part Number	1001312
Size (mm)	2.00 x 1.20 x 0.55
Mounting	SMT
Weight (grams)	0.003
Packaging	Tape & Reel, 1001312 – 1,000 pieces per reel
Demo Board	1001312-04

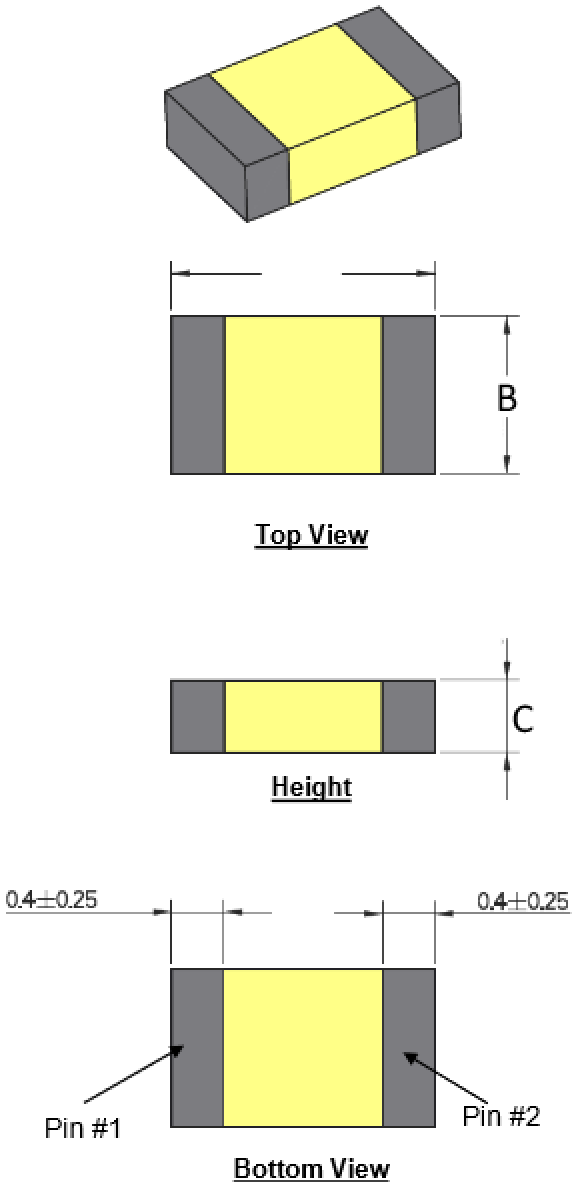
Antenna Dimension and Pad Layout

Figure 1 below shows the Antenna Dimension and Pad Layout for 1001312

Antenna Dimensions

Typical antenna dimensions (mm)

Part Number	A (mm)	B (mm)	C (mm)
1001312	2.0 ± 0.3	1.2 ± 0.3	0.55 ± 0.2



Pin	Description
1	Feed
2	Ground

*Pin #1 and Pin #2 are interchangeable.

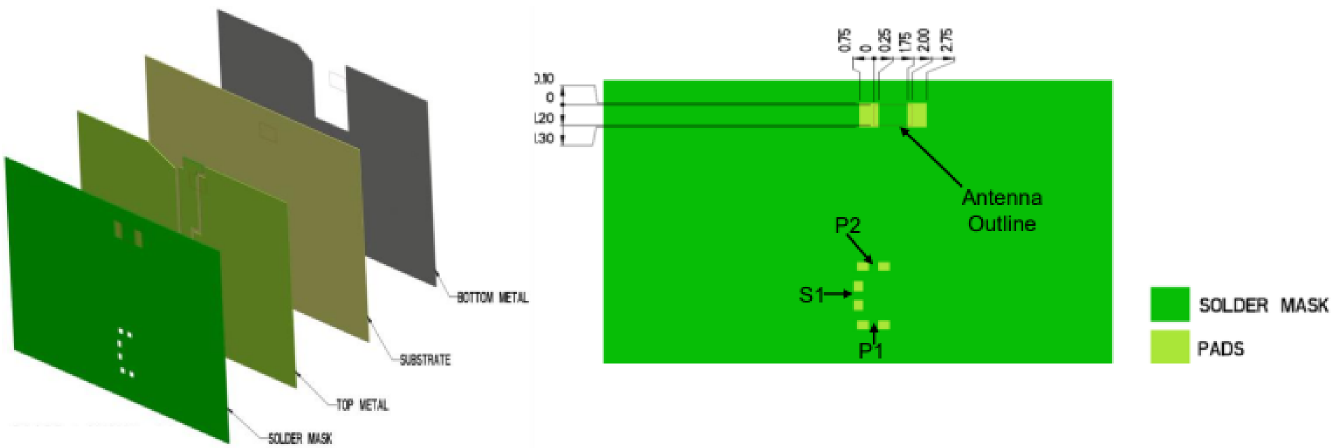
Figure 1: Antenna Dimensions and Pad Layout for 1001312

Antenna Footprint Layout

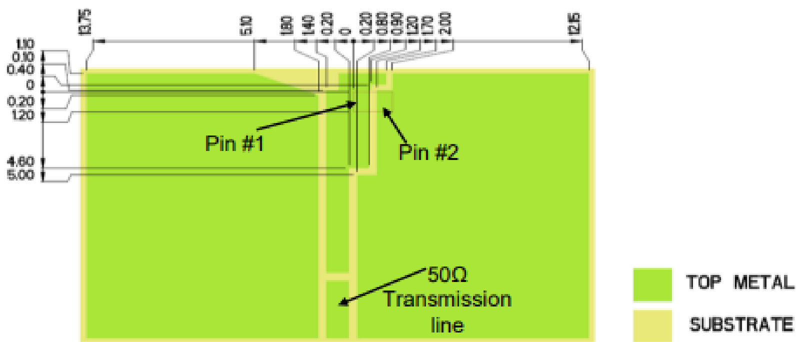
Figure 2 below shows the 1001312 Antenna Footprint and Tuning Layout

Antenna Layout (1001312-04)

Typical layout dimensions (mm)



- Additional VIAS : Diam. 0.2mm to be placed around antenna, (no vias on transmission lines).
- Via holes must be covered by solder mask



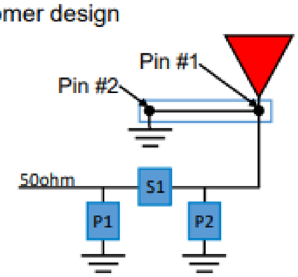
Pin Descriptions

Pin#	Description
1	Feed
2	Ground

Matching Pi Network (Demo Board)

Component	Value	Tolerance
P1	DNI	N/A
S1	0Ω	N/A
P2	DNI	N/A

*Actual matching values depend on customer design



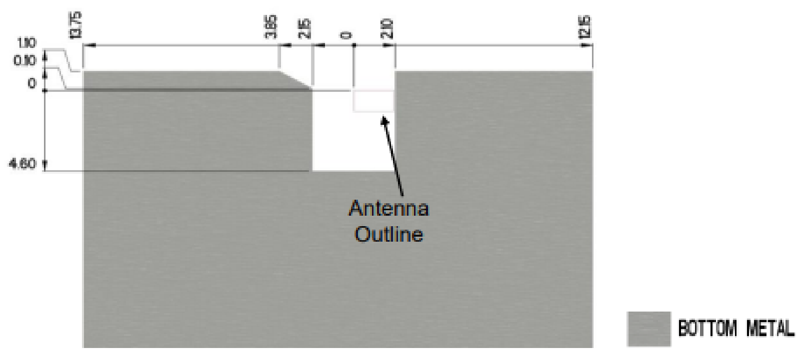


Figure 2: 1001312 Antenna Footprint and Tuning Layout

Typical Measured Data

VSWR, Efficiency and Radiation Pattern

Figure 3 below shows the 1001312 Antenna Typical VSWR & Efficiency Plots on 26 x 25 mm PCB
Figure 4 below shows the 1001312 Antenna Typical Radiation Pattern Plots on 26 x 25 mm PCB

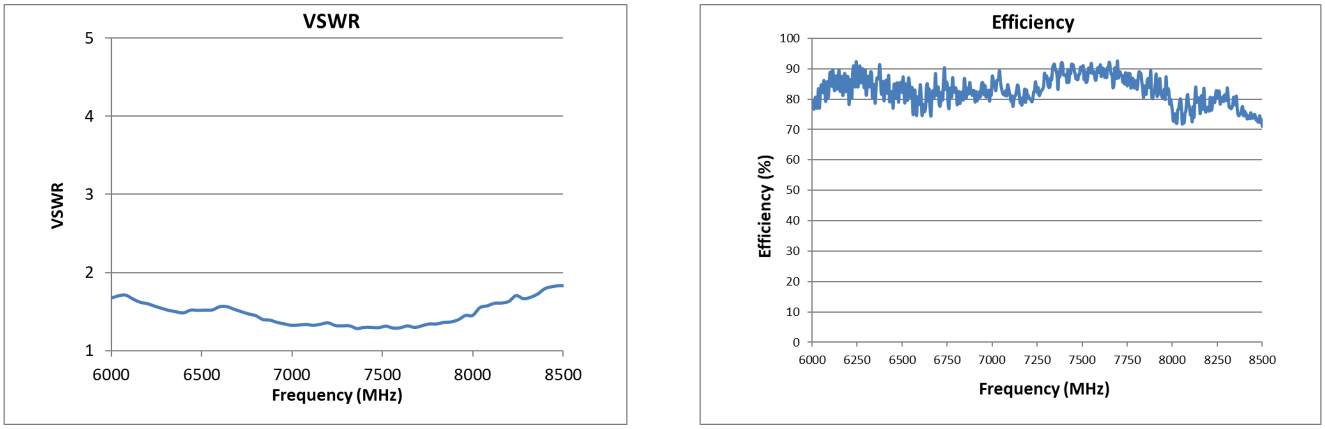


Figure 3: 1001312 Antenna Typical VSWR & Efficiency Plots on 26 x 25 mm PCB

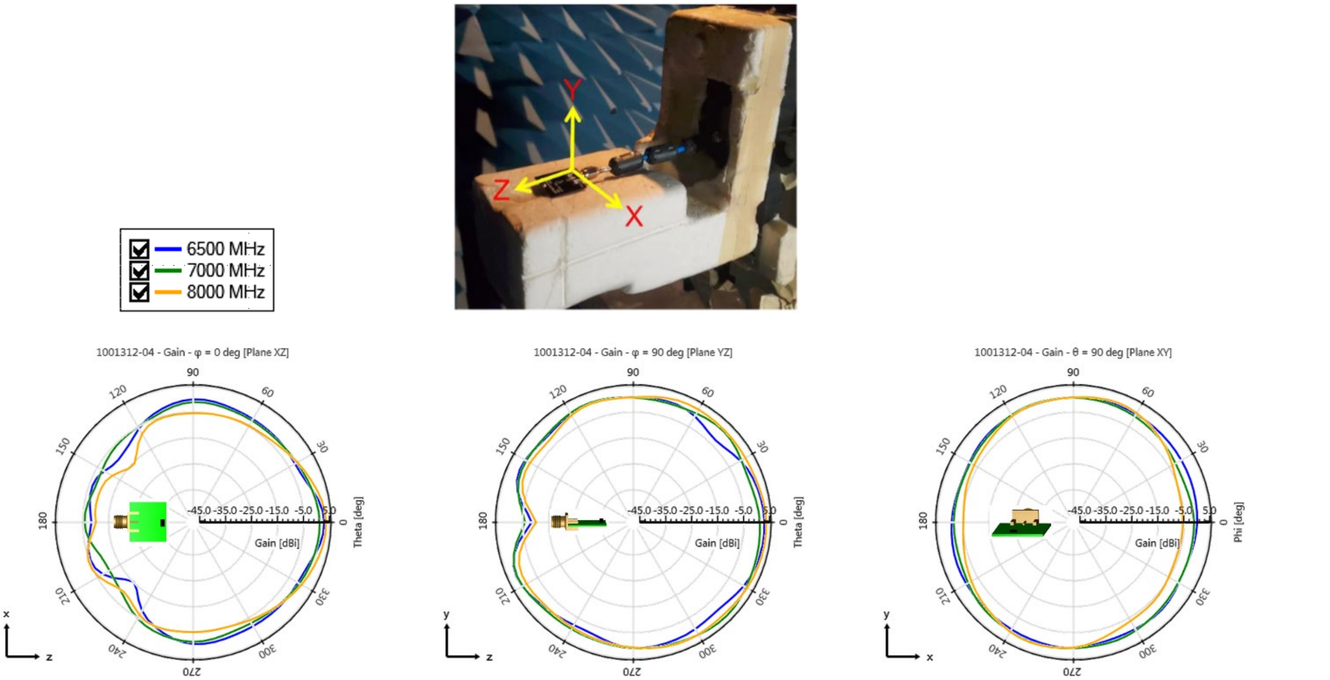


Figure 4: 1001312 Antenna Typical Radiation Pattern Plots on 26 x 25 mm PCB Measured @ 6500&7500&8000 MHz

Antenna Placement Guidelines on PCB

The 1001312 is a ceramic antenna element that can be mounted onto any PCB using Keocera-AVX recommended footprint layout and ground layout, including proper PCB size. This tiny and compact antenna solution can easily be intergraded into a radio module reference design. Antenna placement on module reference design will still need to follow Keocera-AVX recommended antenna location, otherwise the module's PCB ground size may not be able to meet the antenna's requirement.

Antenna should always be placed along the edge of the board unless there are special conditions preventing this.

The antenna can be placed on either the top or bottom side of the PCB. The recommended antenna location is at the center of edge, and the suggested edge length: "A" ≥ 26mm.

Figure 5 shows the optimal antenna placement for 1001312

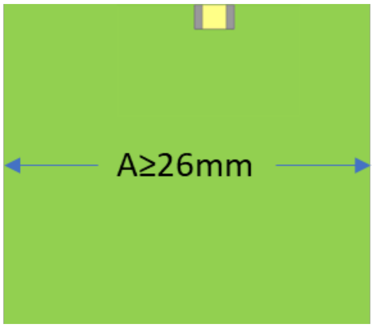


Figure 5: the optimal antenna placement for 1001312

Antenna Tuning Guidelines

In real application environments, variation of the antenna resonating frequency may be caused by the following effects: Different antenna locations, PCB board variations (including PCB size and PCB thickness), Components and shield cans located close to the antenna, outside cover and metal element from inside or outside of device, etc.

Additionally, any plastic loading needs to be considered for fine tuning steps. For example, 2mm thickness PC/ABS material will detune the antenna frequency by ~30MHz.

The following methods can be applied to solve the above effects

- Major Tuning Through Matching Circuit Guidelines
- Minor Tuning Through the Footprint Pad Printed on the PCB
- Change Antenna Location
- Change Antenna Height in Z direction from Ground/Metal
- Change Antenna Distance in Y direction from Ground/Metal
- Extend PCB Ground
- Change PCB Thickness
- MIMO Solutions

Major Tuning Through Matching Circuit Guidelines

Performance can be improved by tuning the matching circuit. Optimum matching values may vary working with different boards transmission line design, different antenna location, different PCB size and antenna working environments. Nevertheless, antenna performance can be improved by modifying the tuning pad and optimizing the matching components accordingly.

Due to the ultra-high frequency band, antenna performance typically will be more sensitive and effective by matching tuning compared to general low and high frequency. So high tolerance components will be recommended for UWB band matching tuning. Here is an example to show the antenna performance could be impacted by applying different matching components.

Figure 6 shows 1001312 with Different Matching Value
Figure 7 shows 1001312 Return Loss and Efficiency Change with Different Matching Values

Component	P1	S1	P2
Matching0 (baseline)	N/A	0Ω	N/A
Matching1	0.1pF	15pF	N/A

Figure 6: 1001312 with Different Matching Value

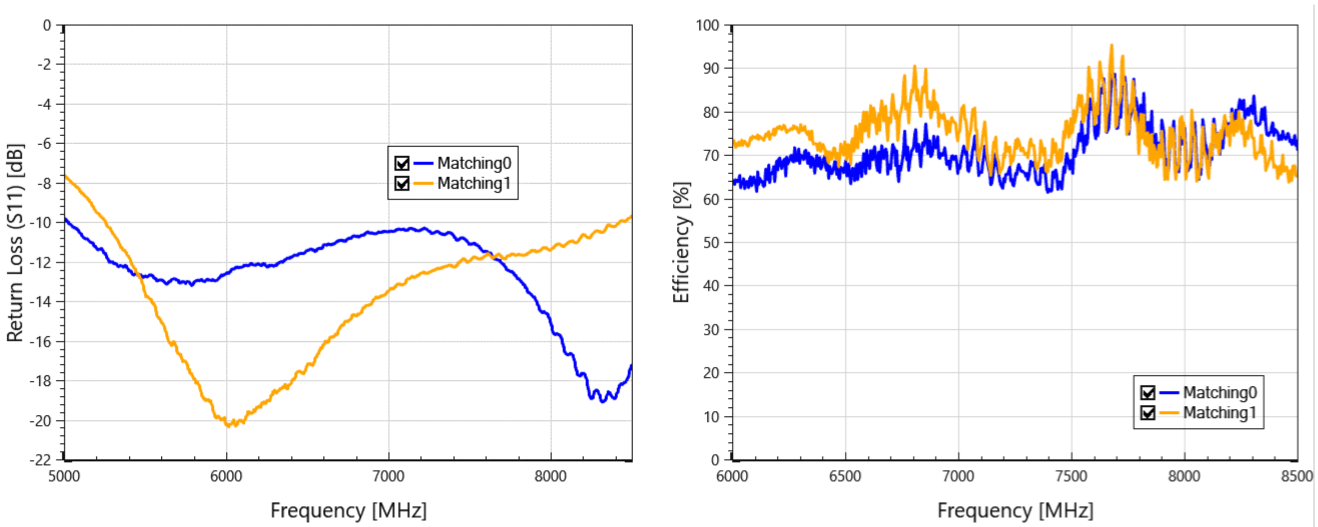
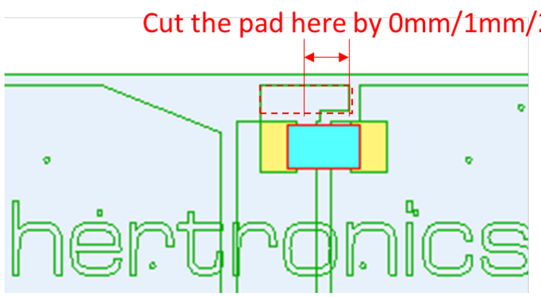


Figure 7: 1001312 Return Loss and Efficiency Change with Different Matching Values

Minor Tuning Through the Footprint Pad Printed on the PCB

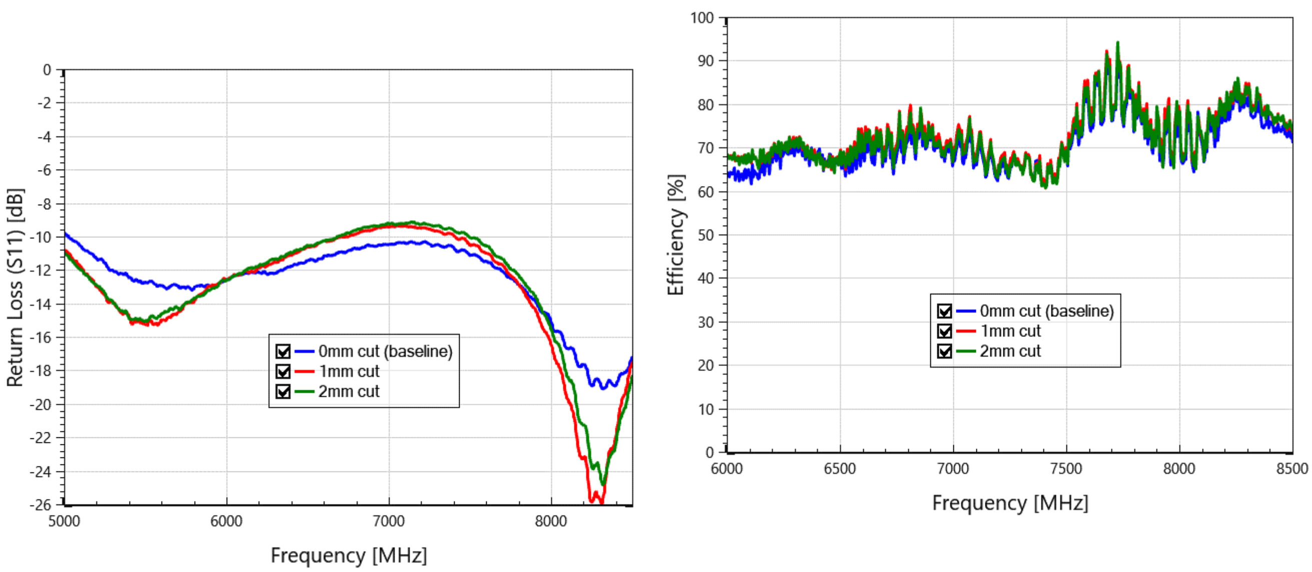
Tuning the pad length on antenna footprint can minor changing the balance of frequency resonance. The default length is the maximum, performance at two edges could be slightly improved when cutting the pad shorter, and in the opposite, the middle frequency will perform slightly better when remain a longer pad length.

Figure 8 shows 1001312 Different Footprint Pad Length Test Configurations
Figure 9 shows 1001312 Return Loss and Efficiency Change with Different Footprint Pad Length



Test Configurations
0mm cut (baseline)
1mm cut
2mm cut

Figure 8: 1001312 Different Footprint Pad Length Test Configurations



Change Antenna Location

Antenna performance can vary with different antenna locations placement. In general, the preferred location is in the center of one PCB edge. The short edge should be exceeded 26mm. For UWB band, the performance will be less effect by the antenna location, but it will prefer to locating on short edge instead of long edge if the short edge could meet minimum 26mm width. The studies below show the antenna performance variation with different antenna locations based on a 150mm x 70mm PCB.

Figure 10 shows 1001312 On Different Locations Of PCB
Figure 11 shows 1001312 Return Loss and Efficiency Change with Different Antenna Location

Test Configurations	Antenna Placement
Location1	long edge _ left
Location2	long edge _ middle
Location3	long edge _ right
Location4	short edge _ left
Location5	short edge _ middle
Location6	short edge _ right

Figure 10: 1001312 On Different Locations Of PCB

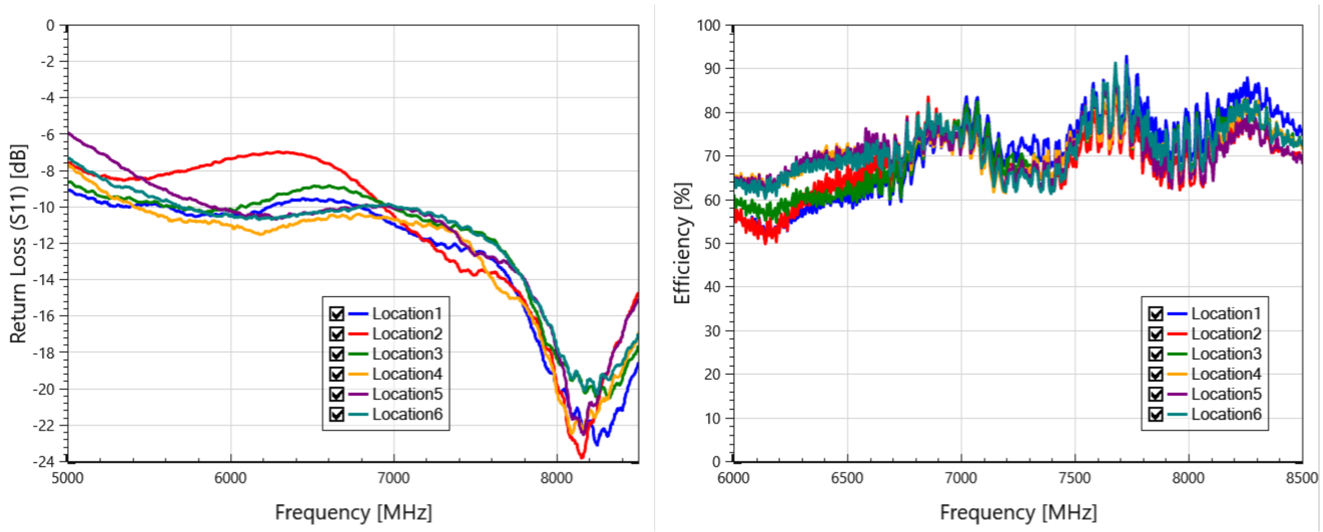


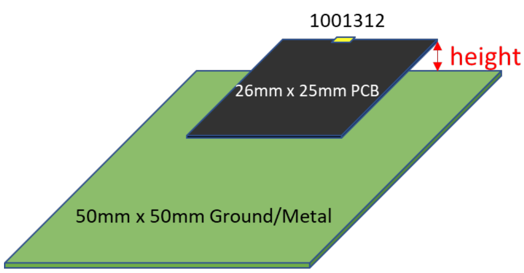
Figure 11: 1001312 Return Loss and Efficiency Change with Different Antenna Location

Change Antenna Height in Z direction from Ground/Metal

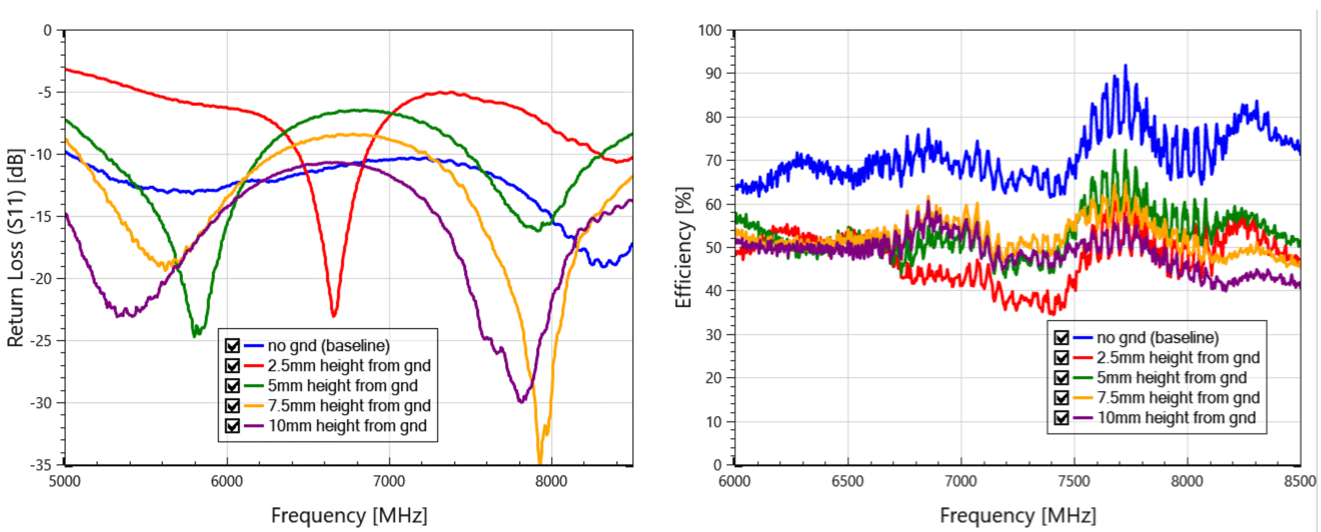
Antenna performance can be impacted by placing the antenna module on a piece of ground or metal, a certain gap between antenna and ground plane is necessary to be added, and the recommended height is greater than 5mm. In general, the larger gap distance, the higher antenna performance will be achieved.

The study below shows how the height in Z direction effect on antenna performance based on 26x25mm antenna module placed on a 50x50mm ground plane.

Figure 12 shows 1001312 With Different Height from Ground
Figure 13 shows 1001312 Return Loss and Efficiency Change with Different Antenna Height



Test Configurations
No gnd (baseline)
2.5mm height from gnd
5mm height from gnd
7.5mm height from gnd
10mm height from gnd

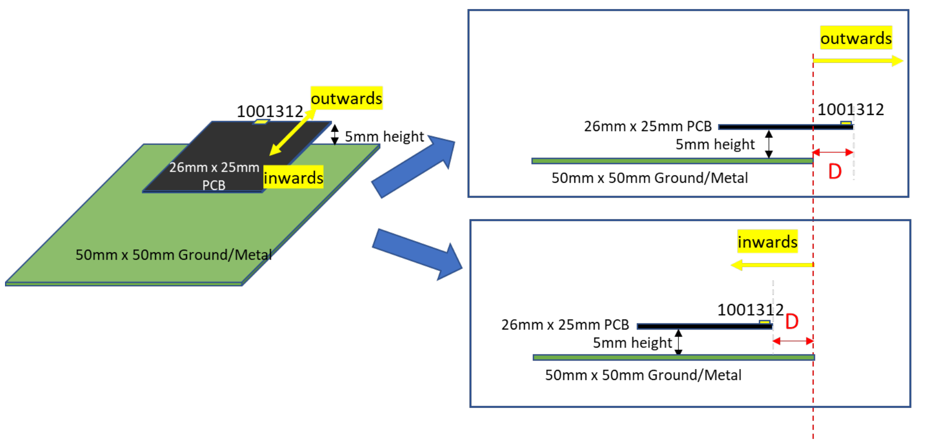


Change Antenna Distance in Y direction from Ground/Metal

Antenna performance can be impacted by placing the antenna module on a piece of ground or metal, a certain ground clearance between antenna module and ground plane is necessary to be added. In general, the more distance moving antenna module outwards the ground plane, the higher antenna performance will be achieved; and in opposite, the more distance moving antenna module inwards the ground plane, the lower antenna performance will be caused.

The study below shows how the distance in Y direction effect on antenna performance based on 26x25mm antenna module placed on a 50x50mm ground plane from 5mm height.

Figure 14 shows 1001312 With Different Distance in Y direction from Ground
Figure 15 shows 1001312 Return Loss and Efficiency Change with Different Distance in Y Location from Ground



Test Configurations
5mm height_0mm in/out (baseline)
5mm height_5mm out
5mm height_10mm out
5mm height_15mm out
5mm height_20mm out
5mm height_5mm in
5mm height_10mm in
5mm height_15mm in
5mm height_20mm in

Figure 14: 1001312 With Different Distance in Y direction from Ground

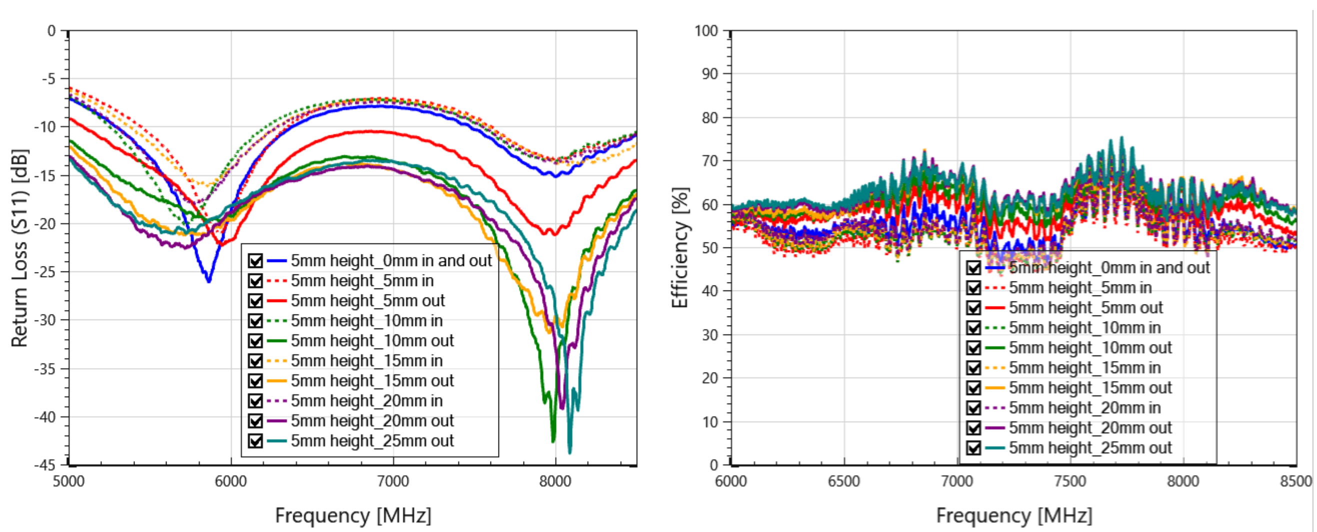


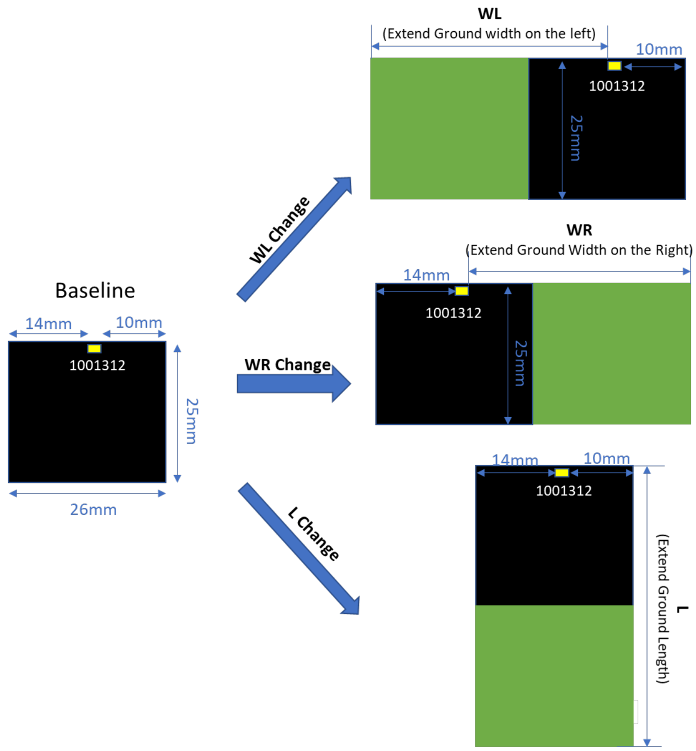
Figure 15: 1001312 Return Loss and Efficiency Change with Different Distance in Y Location from Ground

Extend PCB Ground

In general, The PCB ground width and length is a critical factor for antenna performance, However, for 1001312 UWB antenna, the PCB width and length will have no significant effect on antenna performance.

The study below shows how the ground extension from three directions effect on antenna performance. Based on the result, it is barely impact on antenna performance when extending the ground with “L” length change, and less than 5% performance impact when changing “WL” or “WR”.

Figure 16 shows 1001312 With Extend Ground from Different PCB edges
Figure 17 shows 1001312 Return Loss and Efficiency Change with Different Ground Extensions



	Test Configurations
	Baseline (WL=14mm, WR=10mm, L=25mm)
WL Change	WL=34mm (WR=10mm, L=25mm)
	WL=54mm (WR=10mm, L=25mm)
	WL=74mm (WR=10mm, L=25mm)
	WL=94mm (WR=10mm, L=25mm)
	WL=114mm (WR=10mm, L=25mm)
WR Change	WR=30mm (WL=14mm, L=25mm)
	WR=50mm (WL=14mm, L=25mm)
	WR=70mm (WL=14mm, L=25mm)
	WR=90mm (WL=14mm, L=25mm)
	WR=110mm (WL=14mm, L=25mm)
L Change	L=45mm (WL=14mm, WR=10mm)
	L=65mm (WL=14mm, WR=10mm)
	L=85mm (WL=14mm, WR=10mm)
	L=105mm (WL=14mm, WR=10mm)
	L=125mm (WL=14mm, WR=10mm)

Figure 16: 1001312 With Extend Ground from Different PCB edges

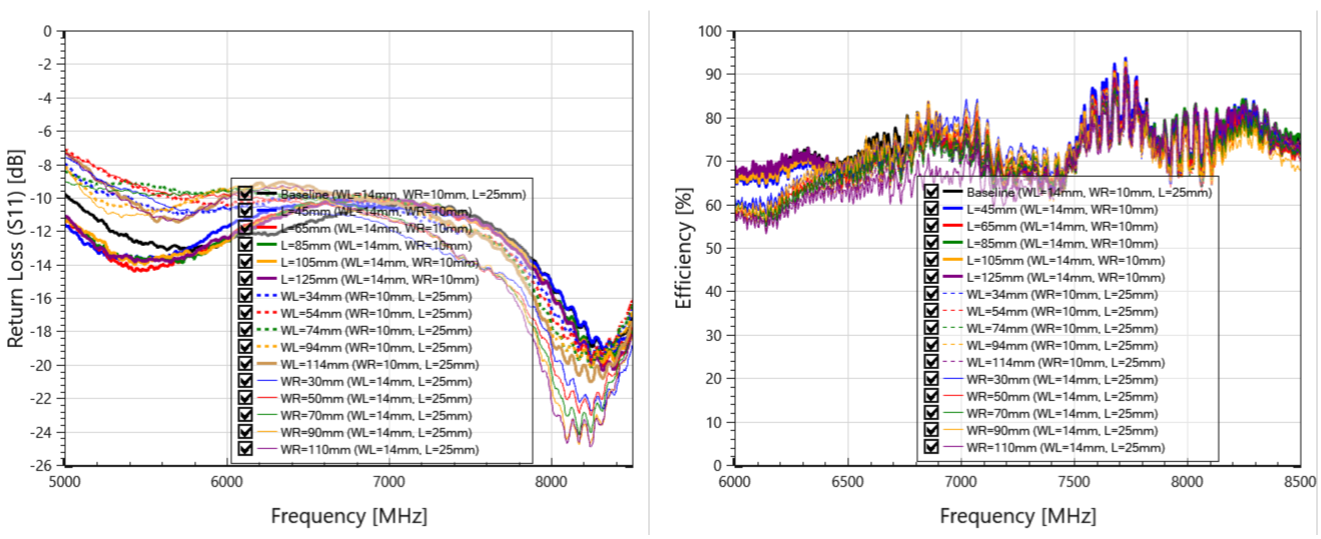


Figure 17: 1001312 Return Loss and Efficiency Change with Different Ground Extensions

Change PCB Thickness

The PCB ground thickness is also a critical factor for antenna performance. The thickness of PCB could directly impact transmission line design which could cause antenna matching change, besides it acts as a material loading underneath antenna structure which could cause antenna frequency shift and performance loss when changing the thickness. Typically, the thicker the PCB, the lower the frequency will be shifted.

Current default PCB thickness is 0.8mm. To achieve the typical UWB performance, be sure the layers layout within the first 0.8mm thickness from top layer is according to KAVX footprint layout, and the rest layers could be clear the ground as much as possible.

The study below shows how the three different PCB thickness (0.8mm/1.6mm/2.4mm) effect on antenna performance with different ground clearance for the rest layers.

Figure 18 shows 1001312 With Different PCB thickness in Different Ground Clearance
Figure 19 shows 1001312 Return Loss and Efficiency Change with Different PCB thickness in Different Ground Clearance

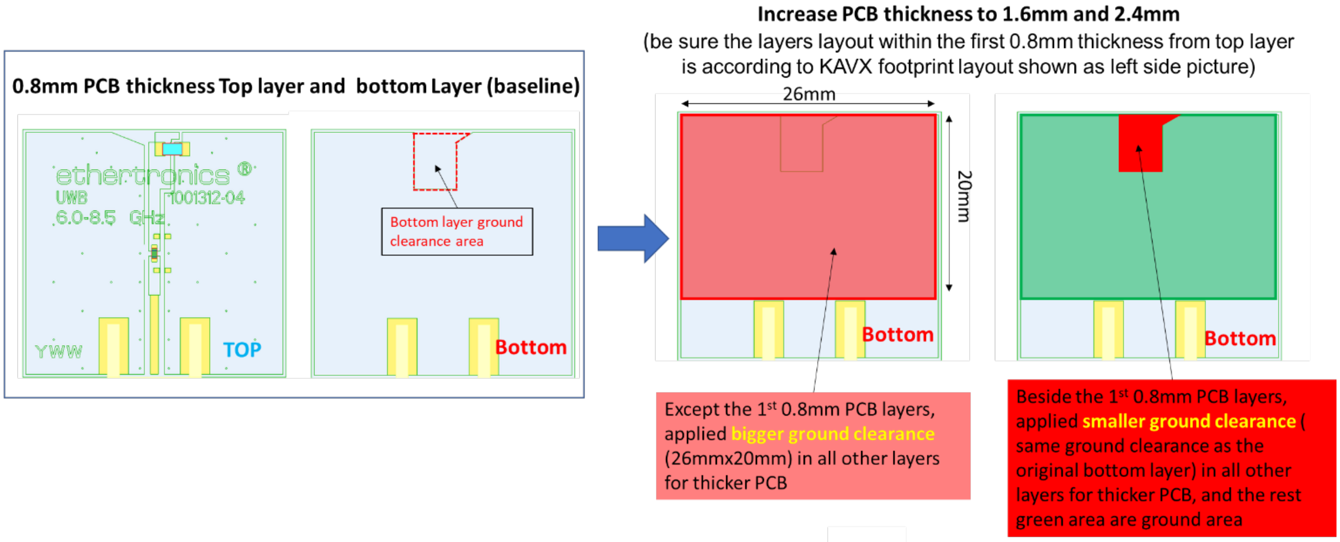


Figure 18: 1001312 With Different PCB thickness in Different Ground Clearance

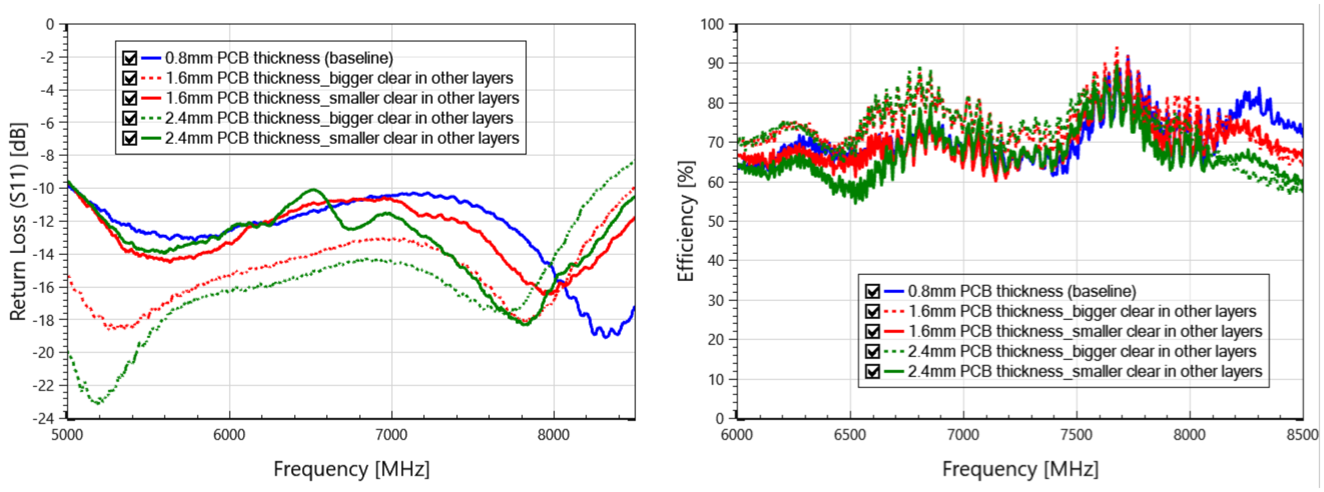


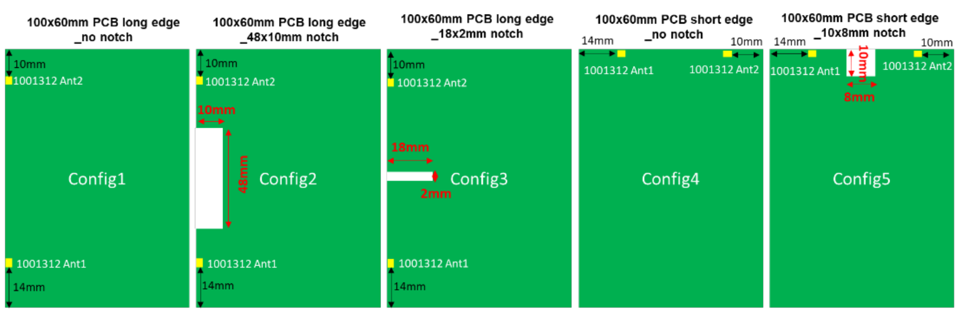
Figure 19: 1001312 Return Loss and Efficiency Change with Different PCB thickness in Different Ground Clearance

MIMO Solutions

MIMO technique requires both two UWB antennas have high performance and good isolations. In general, the minimum two antenna distance need be greater than 20mm. Adding a notch could further improve isolation between two antennas, the notch size and location varies depending on different PCB layout and components environment.

The study below shows 5 test configurations placing two antennas on the same edge of 100mm x 60mm PCB with or without notch.

Figure 20 shows 1001312 With Different MIMO Test Configurations
Figure 21 shows 1001312 Return Loss, Efficiency, and Isolation Change with Different MIMO Solutions



Test Configurations	
Config1	100x60mm PCB long edge _no notch
Config2	100x60mm PCB long edge _48x10mm notch
Config3	100x60mm PCB long edge _18x2mm notch
Config4	100x60mm PCB short edge _no notch
Config5	100x60mm PCB short edge _10x8mm notch

Figure 20: 1001312 With Different MIMO Test Configurations

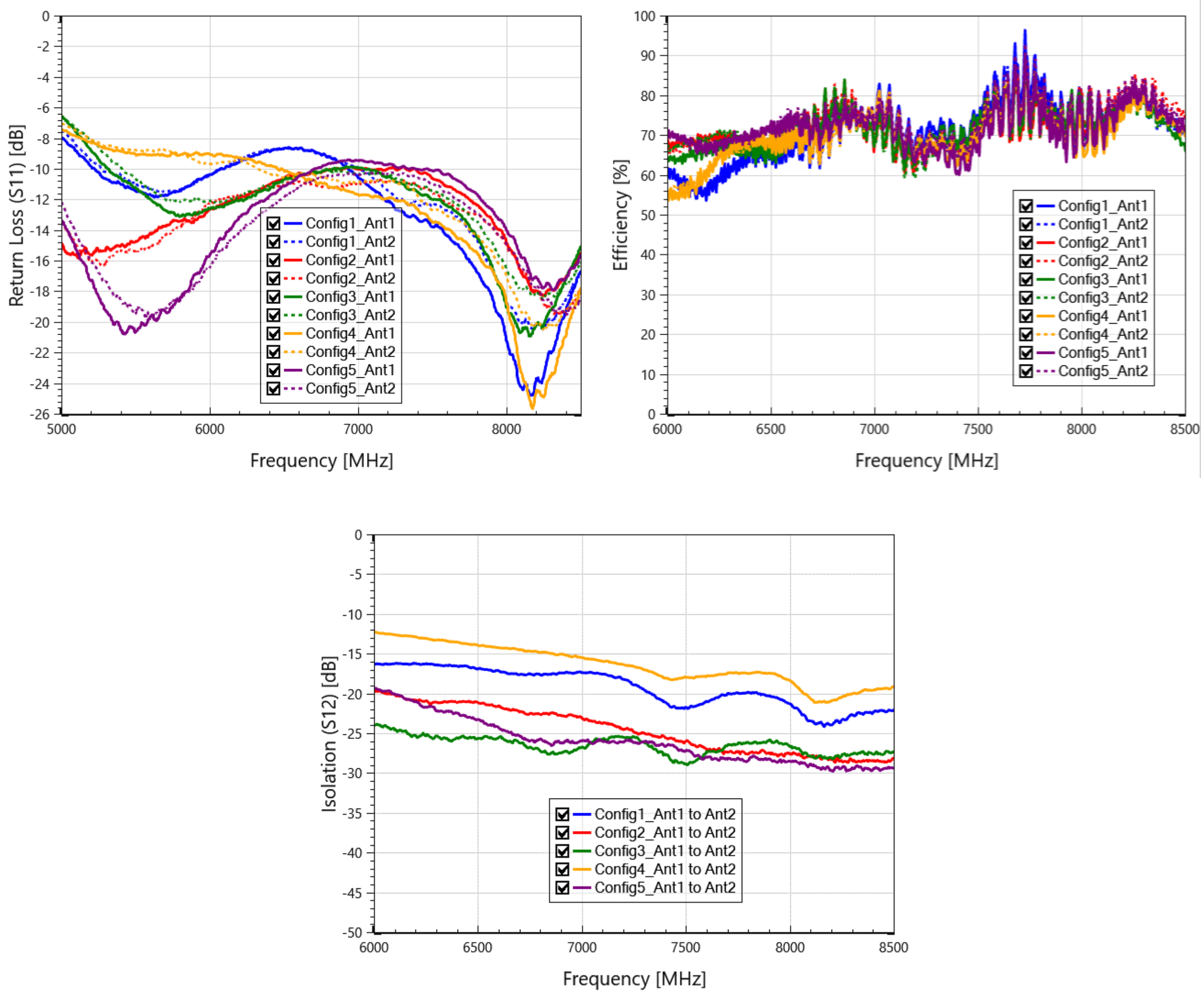


Figure 21: 1001312 Return Loss, Efficiency, and Isolation Change with Different MIMO Solutions

Group and Phase Delay

UWB technology’s precise location monitoring relies on the time domain performance of the system. The study below tests the phase and group delay of two 1001312 antennas with the test setup below in different orientations (Front Side, Back Side, Left Side, Right Side, Top Side) at 6 – 8.5 GHz.

Figure 22 shows the two 1001312 antennas under test with a distance of 400 mm between them
Figure 23 shows the five different antenna orientations tested with the test setup below

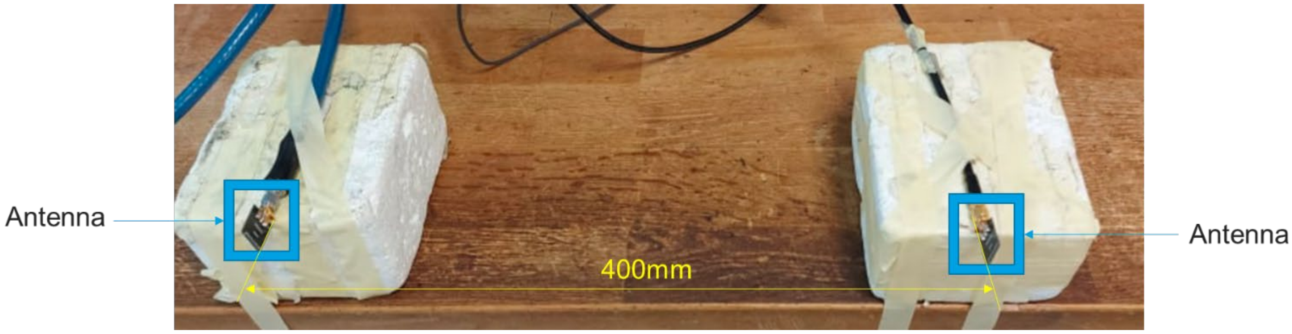


Figure 22: 1001312 Group and Phase Delay Test Setup

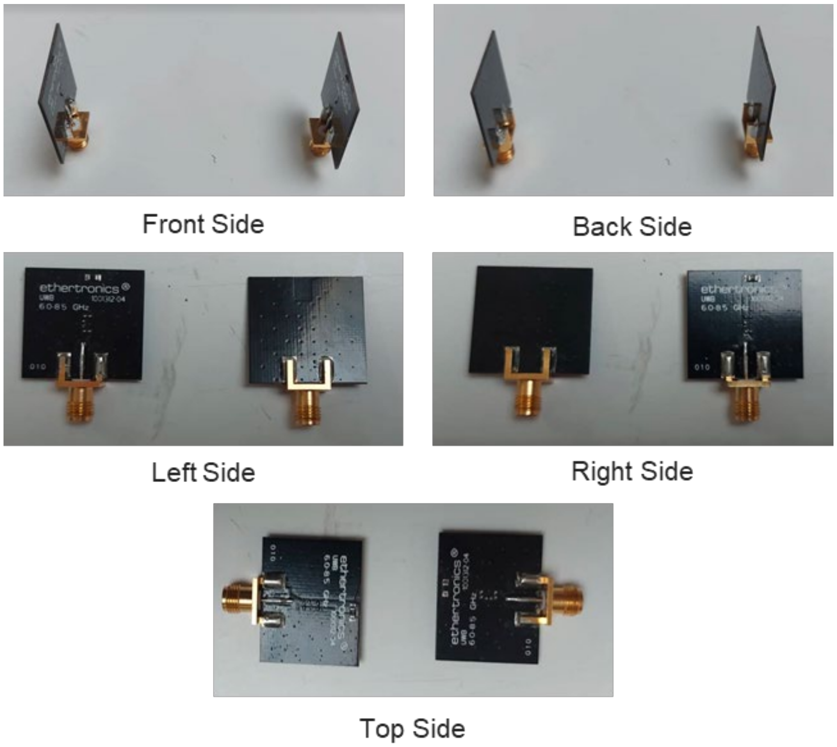


Figure 23: 1001312 Test Configurations for Phase and Group Delay

Figures 24 - 28 show the test results from five different antenna orientations

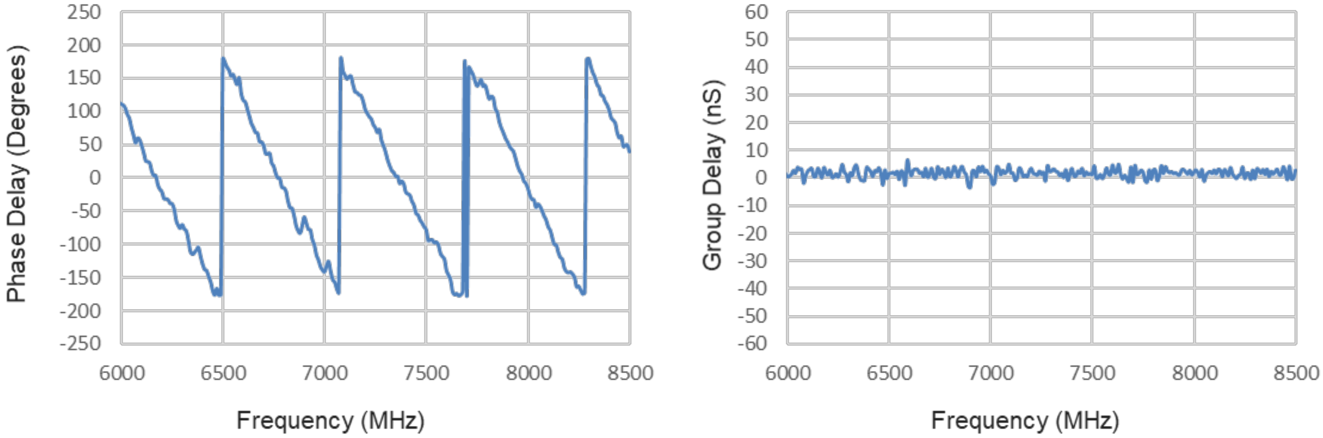


Figure 24: Front Side Phase Delay and Group Delay Test Results

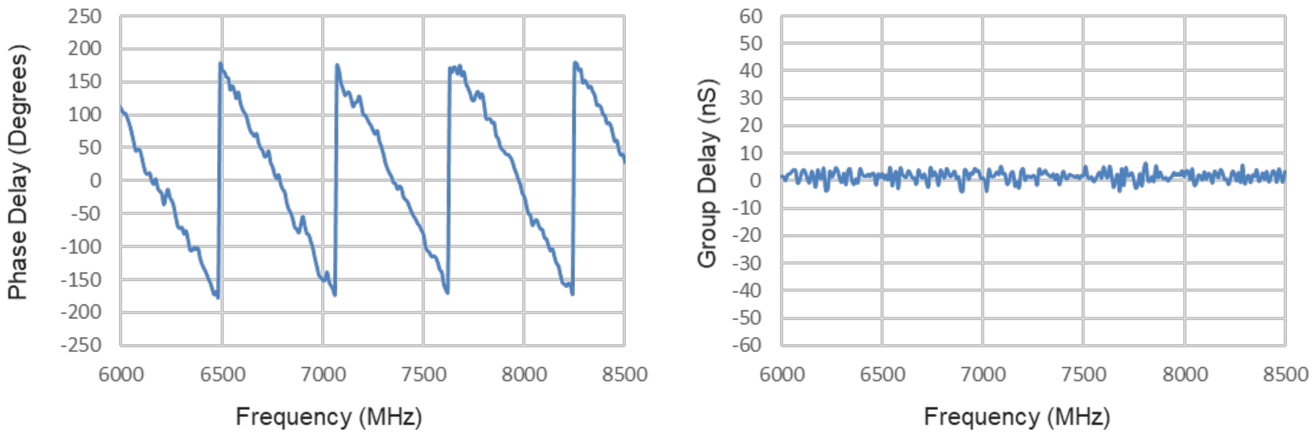


Figure 25: Back Side Phase Delay and Group Delay Test Results

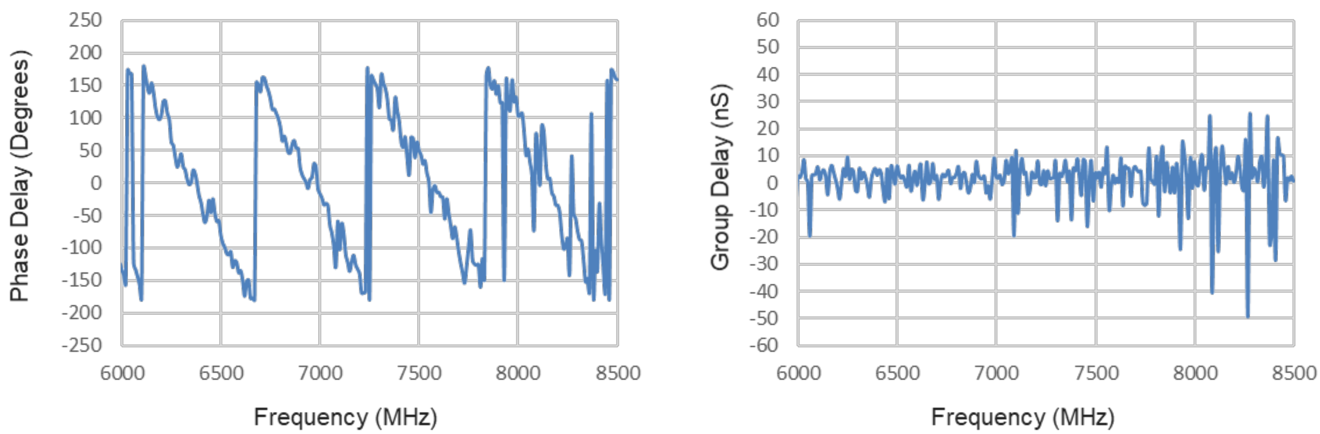
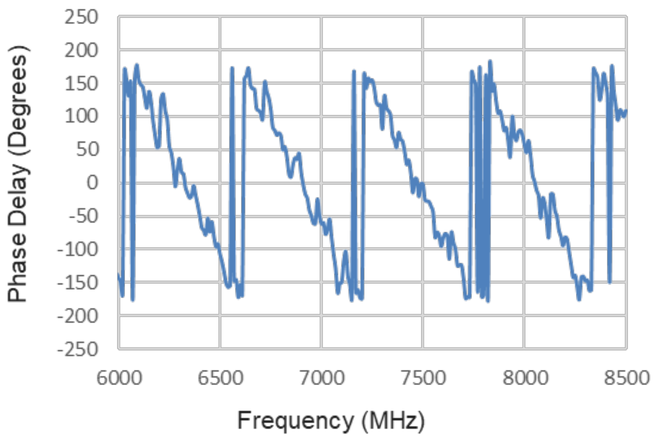


Figure 26: Left Side Phase Delay and Group Delay Test Results



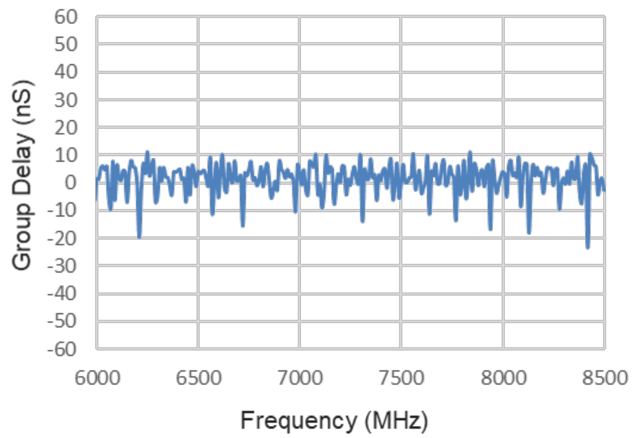
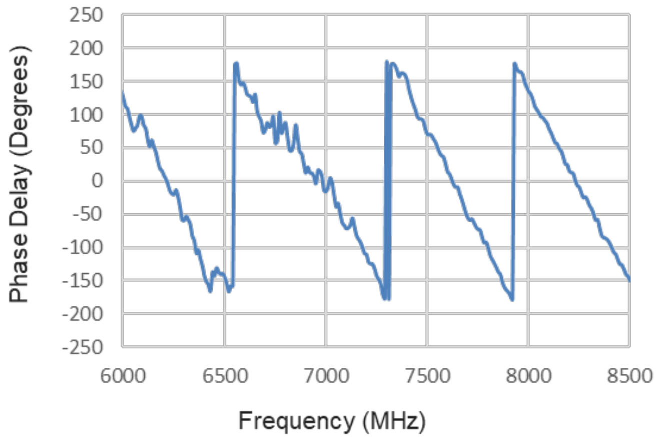


Figure 27: Right Side Phase Delay and Group Delay Test Results



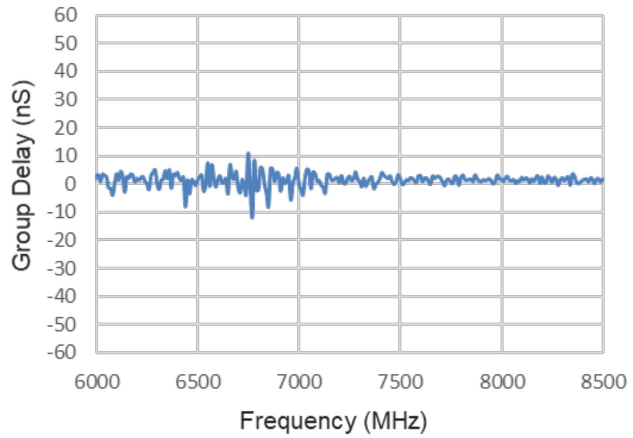


Figure 28: Top Side Phase Delay and Group Delay Test Results

The aim of the group and phase delay study was to assess the performance of the 1001312 UWB antenna. As expected, it shows that the time domain performance (low group delay) depends on the orientation of the antenna.

From the results, it is seen that the 1001312 antenna is providing maximum time domain performance (low group delay) when each of the antennas are vertically mounted (facing each other's back or face) or in the Top Side configuration.